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ROCK CHIPS

ALBERTA GEOLOGICAL SURVEY

Spring/Summer 2002

Mission: Provide the geoscience information and expertise needed by government, industry and the public for earth resources stewardship and sustainable development.

Quaternary Geology and Ice Flow Studies, Peerless Lake (NTS 84B)

The surficial geology maps for the Peerless Lake map area are near completion. They will provide current, geological information and interpretations for mineral exploration and resource development in northern Alberta. The Peerless Lake area has been subjected to several minor Quaternary studies by the Alberta Geological Survey (AGS) since 1992. As part of a multi-year program initiative, AGS completed a surficial mapping program in 2001-2002. The impetus for this recent study was the discovery of 36 kimberlite pipes in the Buffalo Head Hills - Loon River Lowlands. Quaternary studies in the Peerless Lake region have important implications for exploration of kimberlites and other mineral deposits using drift prospecting.

The physiography of the map area is dominated by the Buffalo Head Hills to the west and the Peerless Highlands to the east, which are separated by the Loon River Lowlands. The highlands are characterized by extensive areas of stagnant ice terrain that is dissected by multiple meltwater channels. In contrast, organic terrain, interspersed with glaciolacustrine and glaciofluvial sediments, occupy the lowlands (Figure 1). Drift

Figure 1. Stagnant ice moraine on the Peerless Highlands. These ringed or 'doughnut' moraines are interpreted to have been formed from debris-rich ice slowly decaying and melting some time after deglaciation. The straight, linear 'roads' are seismic lines.

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thickness is variable, from <2 m in the Buffalo Head Hills to >200 m in the Loon River Lowlands.

In a few places, outcrops of kimberlite (e.g., K5 and K6) in the Buffalo Head Hills form small, prominent knobs that protrude above the surrounding stagnant ice terrain. On the top of the Buffalo Head Hills, areas of thin (<2 m) till were found overlying sandstone and shale bedrock (Figure 2, next page). The occurrence of these outcrops was previously unknown; palynological analysis shows the bedrock is an outlier of Wapiti Formation sandstone of Late Campanian age. This is considerably younger than the previously mapped Smoky Group. Additionally, a thin veneer of preglacial (Tertiary?) quartzite gravel discontinuously overlies the bedrock in these areas of shallow drift cover.

An extensive esker and ice-contact meltwater complex was observed in the southwest corner of the map area. Other notable glaciofluvial features include the Trout River meltwater channel, which occurs near the western edge of the Peerless Highlands, and a kame complex adjacent to Gods Lake. These are excellent sources of aggregate in a region that has limited aggregate resources.

Special attention was paid to the various ice flow indicators in the region. Ice flow history and flow directions in northern Alberta are generally interpreted exclusively from streamlined surface landforms. However, it must be stressed that these landforms only represent the final chapter of a long story of ice movement during the Late Wisconsin. The sparse occurrences of outcrop and the complete lack of preserved striae on the soft clastic bedrock prevent any preliminary interpretations on early and regional glacial flow patterns. Pebble fabric measurements on surface tills are generally parallel to the regional landforms. Widespread deposition of englacial and supraglacial debris, in the form of thick, hummocky, stagnant-ice terrain, also masks regional ice flow indicators.

Regardless of these difficulties, an interpretation of ice flow history and directions in the Peerless Lake area has been determined from streamlined landforms, glacial thrust ridges and pebble fabric measurements (Figure 3). Early glacial flow was likely dictated by topography, but as ice sheet thickness increased during the glacial maximum (*ca.* 22,000 to 18,000 years before present or B.P.), ice was unimpeded by local topography and

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Figure 2. A veneer of till overlying sandstone bedrock exposed in a borrow pit on the Buffalo Head Hills.

generally flowed to the southwest. Flutings scoured into the bedrock on the Buffalo Head Hills, and a well-preserved crag and tail landform at the K5 kimberlite outcrop, are parallel to this regional ice flow interpretation. In contrast, flutings and linear landforms on the northeastern flank of the Peerless Highlands indicate a south-southeasterly ice flow. This suggests that late-stage ice was deflected due to topographic control of the thinning ice sheet. A rare boulder pavement was also discovered at the Red Earth airport. Striae, measured from the planed tops of the boulders, indicate the surface till in the Loon River Lowlands was deposited by ice flowing southward (188°). Then, during early deglaciation (*ca.* 13,000 to 11,000 years B.P.), several areas were submerged by glacial lakes as the northward-retreating ice blocked meltwater drainage. Finally, beautifully preserved flutings in the southeast suggest that southwestwardly flowing ice re-advanced into a large glaciolacustrine lake that occupied the Wabasca River lowland to the northeast (Figures 3 this page and 4 next page).❖

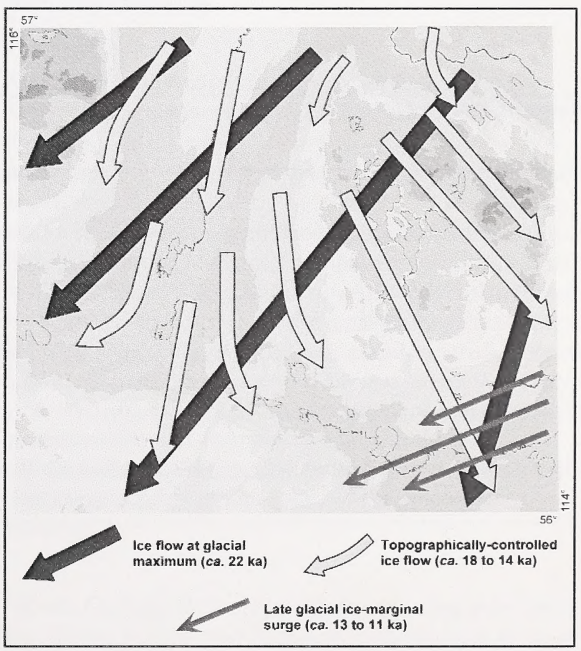
57°
116°
114°
56°
Ice flow at glacial maximum (ca. 22 ka)
Topographically-controlled ice flow (ca. 18 to 14 ka)
Late glacial ice-marginal surge (ca. 13 to 11 ka)

Figure 3. Interpreted ice flow history of the Peerless Lake area during the Late Wisconsin glacial event.

Figure 4. Flutings south of the Trout River. The flutings contrast well with the fens and bogs, which overlie glaciolacustrine sediments. These streamlined landforms represent a late glacial surge into a proglacial lake during early deglaciation of the region.

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The Clearwater - Grand Rapids Aquifer System...	Kevin Parks	(780) 427-2949

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Coalbed Methane in Alberta

Coal is a rock derived from organic matter that accumulates as peat and undergoes subsequent burial. The organic matter undergoes compaction, dewatering and modification by bacterial, geochemical and thermal processes. The resulting product is coal, and the degree of alteration is indicated by the rank of coal. With increasing burial depth, the plant material undergoes coalification, progressively losing moisture and volatile matter, while increasing the heating value, carbon content and reflectance. Low rank coals, such as lignite and sub-bituminous, have relatively high concentrations of moisture and other volatile compounds and low carbon contents. Higher rank coals (bituminous to anthracite coals) have increased carbon content and lower volatile matter concentrations.

Significant volumes of methane may be generated through the thermal maturation of a coal seam. Furthermore, biogenic methane may be generated during the coalification process if proper conditions for bacterial activity are present.

Unlike conventional reservoirs, where gas is held within the pore space of the host reservoir rock matrix, coalbed methane (CBM) is adsorbed onto and within the organic matrix of the coal. Pressure holds the methane within the coal matrix. In order to release the methane, the pressure must be reduced, typically by producing water from the coal seam, thereby allowing gas to desorb from the coal matrix. Natural, regularly-spaced fractures that occur within coals (coal cleats) act as conduits for gas to migrate from the matrix into a wellbore for production. Coal cleats also act as conduits for water removal to assist in pressure reduction in the coal seam. One of the main challenges in coalbed methane production is finding areas with adequate permeability pathways (cleats, fractures) to allow dewatering and gas movement within the coal seam.

Close-up of a coal seam showing well-developed cleats.

Dragline at Whitewood mine exposing the Ardley Coal Zone.

Alberta has substantial coal resources (in excess of $3x10^{12}$ metric tonnes) underlying the Plains and Foothills. Coal is mined at shallow depths to provide a fuel source for mine-mouth power plants and metallurgical-grade coal is mined in the foothills for the steel industry. Coal underlies much of the Plains and Foothills at depths currently too great for economical mining; however, these coals are now being investigated for CBM potential. The potential gas held within these coal deposits has been estimated to range anywhere from $1.42 \times 10^{12} m^3$ (50 trillion cubic feet, tcf) to greater than $1.56 \times 10^{13} m^3$ (550 tcf). The wide range of estimates of gas potential stems from the sparse data available on CBM content. Even less is known about coal reservoir characteristics and producibility of the potential resource.

Alberta Geological Survey, with an operating grant from the Alberta Science and Research Authority, has initiated studies on coal and coalbed methane potential within Alberta. One study focused on defining coal and CBM

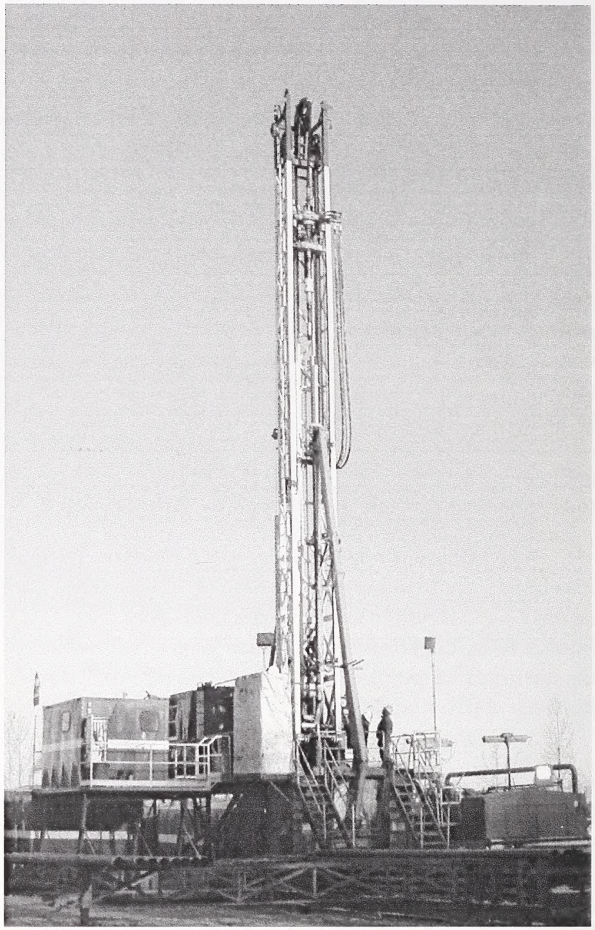
resources for the Upper Cretaceous to Tertiary strata of the Alberta Plains. An extensive coal database, including over 7500 wells, 32 000 coal picks and 16 000 stratigraphic picks, was constructed. Coal resources, gas concentration and potential gas resource density maps, and summations were generated for each of the seven major coal zones within the Plains study, namely, the Ardley, Carbon/Thompson, Daly/Weaver, Drumheller, Lethbridge, Taber and McKay coal zones.

The potential gas resources for the Upper Cretaceous-Tertiary strata of the Alberta Plains were estimated in this study at 5.20 x 10^{12} m^3 (184 tcf). This figure includes all coal within the evaluated coal zones, regardless of depth and net coal thickness. Constraining resources to depths >200 m and net coal thickness of a coal zone to >1 m (common industry constraints), a CBM gas resource potential of 4.13 x 10^{12} m^3 (146 tcf) is indicated. No data are currently available to evaluate the gas potential of interbedded clastics, which may also contribute to the total gas potential of a coal zone. The ultimate producibility of CBM resources is currently uncertain. Limited commercial production has been established, and several companies are actively exploring for coalbed methane within the Alberta Plains with encouraging initial results.

Major coal resources of the Foothills are present in five stratigraphic coal zones: Kootenay, Gething, Gates, Brazeau and Coalspur. For coalbed methane evaluation purposes, resources were estimated on the basis of shallow (200 to 1000 m depth) and deep (>1000 m depth) coal zones. The gas content of all shallow coal zones totals about 8.78 x 10^{11} m^3 (31 tcf) of methane, which is considered an inferred, initial in-place coalbed methane resource estimate based on limited data.

The only (limited) Foothills CBM production has been from the southern Alberta Kootenay coal zone, which is very prospective for coalbed methane production. The shallow Gates coal in the central and northern Foothills is also prospective, but needs additional testing. The best potential for coalbed methane in the Coalspur coal zone is in the Edson area (Entrance Syncline and Triangle Zone).

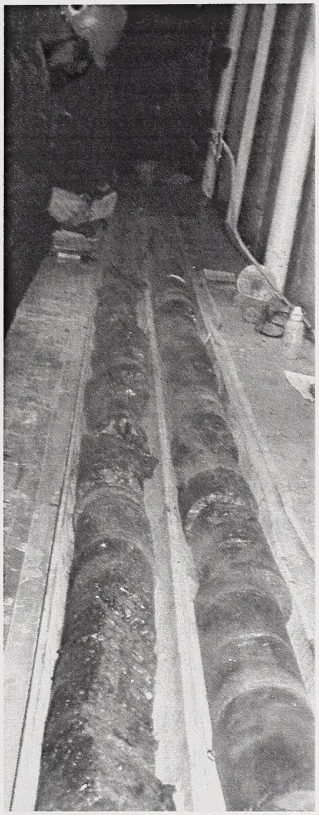
The CBM potential and producibility of any coal-bearing stratum are strongly affected by the hydrogeological regime of formation waters and by coal permeability, which depends on the effective stress regime of the coal



Coalbed methane drilling rig.

seams. The study of the hydrogeological and stress regimes of the Upper Cretaceous-Tertiary coal-bearing sedimentary succession in the Alberta Plains shows that the flow of formation waters in these strata is driven by gravity (topography) and erosional rebound. The flow is also controlled by rock permeability, gas generation and capillary pressure to gas (relative permeability). The minimum effective stress, which affects coal permeability by closing fractures, increases west-southwestward, from zero at the erosional edge of the strata to approximately 20 MPa (megapascal) near the Rocky Mountain deformation front. Fractures, including those in coal seams, will generally be vertical and will propagate on a southwest-northeast axis along the direction of the maximum horizontal stress.

From the point of view of produced water, the salinity of formation water in shallow coal seams, where the flow is driven by topography, is low— generally less than 1500



Coal core recovered for CBM testing.

mg/l— it may reach 3000 to 5000 mg/l. The salinity of formation water in the deeper strata in west-central Alberta, where the flow is driven by erosional rebound, is significantly higher— reaching up to 18 000 mg/l. This will affect treatment and/or disposal strategies regarding the water produced concurrent with coalbed methane.

Ongoing CBM studies at Alberta Geological Survey include the evaluation of coal and CBM resource potential for Lower Cretaceous coals in the Alberta Plains and investigating geological controls (including structural and sedimentological) on CBM potential. Through government and industry collaborations, coal characterization and coalbed methane testing continue to provide new data to assist in interpreting and understanding Alberta's coalbed methane potential.❖

Upcoming publications on CBM:

- Update on the evaluation of the coalbed methane potential of the Foothills/Mountains of Alberta. Langenberg, C.W., Beaton, A. and Berhane, H.

- Coal and coalbed methane potential of Upper Cretaceous-Tertiary strata, Alberta Plains. Beaton, A., Pana, C., Chen, D., Wynne, D. and Langenberg, C.W.

- Coalbed methane database for the Upper Cretaceous-Tertiary plains region of Alberta. Wynne, D., Beaton, A., Pana, C. and Chen, D. (report and CD database)

- Hydrogeology and stress regime of the Upper Cretaceous-Tertiary coal-bearing strata in Alberta Bachu, S. and Michael, K.

The Clearwater - Grand Rapids Aquifer System: A Key to Satisfying Water Needs for In Situ Oil Sands Development?

The Lower Cretaceous Clearwater and Grand Rapids formations host numerous small gas pools in that part of the EUB-designated Athabasca Oil Sands Area lying south of Fort McMurray, Alberta. Their major contribution to Alberta's economic growth may actually lie in their potential to be a huge underground reservoir of groundwater. Though brackish and undrinkable in nature, this groundwater, once treated, is generally suitable for making steam at in situ oil sands projects,.

The Clearwater and Grand Rapids formations are each composed of a number of ancient shorelines. Each shoreline can be thought of as a ribbon of fine sand that grades laterally into silty mud offshore, just like modern-day beaches at the ocean. These particular shorelines trended southwest to northeast. They also stepped northwestwardly through geological time as the shorelines followed the retreat of a prehistoric sea. That prehistoric sea passed through the Fort McMurray area about 110 million years before present.

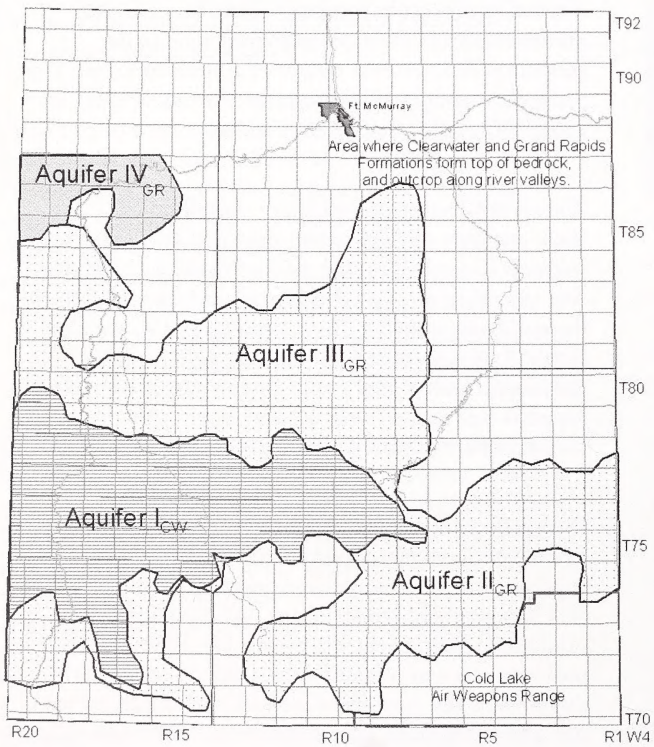
The older Clearwater Formation shorelines tended to stack one atop another, rather than step out. This pattern suggests to geologists that the earth's crust in the area was subsiding at a rate that almost matched the rate of the sea's retreat during Clearwater time. The younger Grand Rapids Formation shorelines tend to step out in succession, rather than stack. To geologists, this pattern suggests that the sea's retreat was more rapid than local crustal subsidence during Grand Rapids time.

During these depositional episodes, there were times when the sea returned to flood the shorelines for relatively short (geologically speaking) periods of time. When those flood pulses ended, the shorelines re-established themselves, but with local differences in position, size and orientation. As they re-established themselves, the younger shorelines sometimes cut into the underlying older shorelines, which otherwise would have remained buried beneath the mud of the previous pulse of flooding.

The tendency of the shorelines to stack, downcut and intersect resulted in an areally extensive sandstone complex, characterized by many vertical and lateral sand-on-sand bed contacts. And because shoreline sands were well-sorted by waves and currents, the resulting sandstone can be very porous and permeable. As a consequence of this fortuitous combination of geometry, extent, thickness, sorting and interconnectivity, the sandstone beds of the Clearwater and Grand Rapids formations make good to excellent aquifers.

AGS used slice-map techniques to investigate the internal architecture of this aquifer system. Preliminary analysis shows that it may be reasonable to divide the system into four distinct regional aquifers. These are labelled as aquifers I_{CW}, II_{GR}, III_{GR}, and IV_{GR} on the accompanying figure. This four-fold subdivision is based on observations from the slice maps of the degree of vertical stacking of sandstone beds within each aquifer, as well as the degree of relative hydraulic isolation between the aquifers afforded by the regionally extensive shale beds marking flooding events. There were certainly more than three or four flooding episodes during Clearwater to Grand Rapids time, but the slice maps suggest that only three or four are regionally extensive enough to act as hydraulically-significant features at the regional scale.

If the shorelines had been completely isolated after burial, then the water entombed in the pore space between the sand grains would have remained as salty as seawater, or higher, due to dissolution of the sand grains over time. But the shoreline sandstones are not isolated. Rather, they are hydraulically connected to the water-cycle at the earth's surface. In the groundwater leg of the water cycle, freshwater from rain or snow percolates into the ground under gravity, recharges and travels through the interconnected pore network of soils and rocks, and eventually discharges to surface at springs or as baseflow to muskeg, lakes, creeks, sloughs and rivers at lower elevation than the recharge areas. The groundwater dissolves minerals and mixes with older groundwater along its flow path, so discharging groundwater is usually more mineralized than recently recharged groundwater. The Clearwater and Grand Rapids sandstones are buried 150 to 300 metres below the ground surface over much of the Athabasca Oil Sands Area south of Fort McMurray, so the rate of mixing and flushing is slow, and there has not yet been sufficient time to flush out all of the original seawater. Thus, the groundwater in these aquifers is brackish in chemical quality.



Regional aquifers of the Clearwater and Grand Rapids Formations, Athabasca Oil Sands Area south of Fort McMurray.

In the area southeast of the City of Fort McMurray, these formations actually form the uppermost bedrock. As well, they are exposed as outcrops in river valleys and on hillsides. Here mixing and flushing by relatively young groundwater of meteoric origin have been much more effective, and consequently the groundwater is fresher and drinkable. This area is noted on the accompanying figure.

AGS is presently using high-resolution stratigraphic techniques to better understand the internal architecture of these complex aquifers. This work will lead to better prediction of aquifer responses to long-term groundwater extraction by the oil sands industry. Better forecasts of aquifer response to pumping will help ensure the effect of the oil sands industry growth in this area are properly understood and regulated.❖

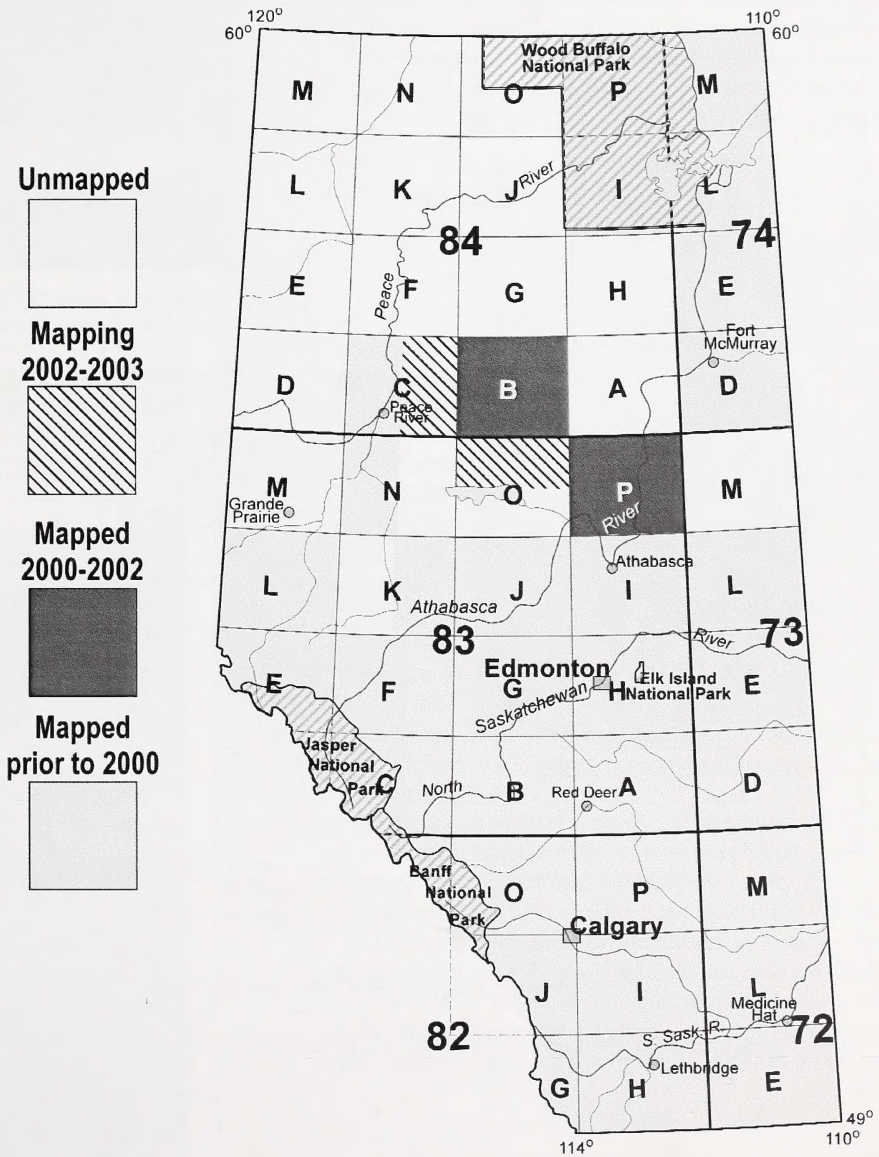
Surficial Mapping 2002-2003

This year, the Alberta Geological Survey marks the third year in its long-term, regional surficial mapping initiative for northern Alberta. Mineral exploration for kimberlite, uranium and shallow gas energy targets remain active in northern Alberta. Thus, the Alberta Geological Survey continues to support the exploration community by providing baseline geological information.

The goal this upcoming field season will be to map the northern half of the Lesser Slave Lake (NTS 83O) and the eastern half of the Peace River (NTS 84C) map areas (see figure). The western half of the Peace River area (NTS 84CW) was previously mapped by L.L. Leslie and M.M. Fenton and released in 2001 as Special Report 10 "Quaternary Stratigraphy and Surficial Geology Peace River – Final Report." This prior mapping information will be incorporated with data collected during this summer's field season. The updated and merged results will be shown in the recently revamped surficial map scheme to produce a regional, surficial geology map for the entire Peace River map area.

Maps containing surficial geology information, Quaternary stratigraphy and glacial history are essential to mineral exploration in northern Alberta. The surficial geology map also provides important information on the various types of surficial materials and ice flow transport directions. As well, it assists in delineating regions containing preferred sampling media (e.g., till, stream sediments or soils) for drift prospecting surveys. Through this work, AGS will provide basic geological information for mineral exploration and resource development in northern Alberta.

For other information about this project, see the Fall/Winter 2002 Rock Chips for preliminary scientific discoveries and highlights from the Slave Lake – Peace River surficial mapping program.❖



Surficial mapping status for Alberta.

Quaternary Stratigraphy and Bedrock Topography Northern Alberta

The primary purpose of this AGS project is to provide a better understanding of drift thickness and stratigraphy in northern Alberta. Other information arising from the project includes: bedrock topography, drift characteristics, Quaternary stratigraphy and history, and shallow bedrock geology. These data will act to support exploration and development in the mineral, energy and forestry industries.

Auger coring in northern Alberta.

During 2002 - 2003, efforts will focus mainly on two map areas and one drilling program. In the Peace River map area (NTS 84C), the subsurface data will be collected to prepare bedrock topography and drift thickness maps for release next year. In northwestern Alberta, (NTS 84K, 84L, 84M and 84N), a multi-year project will be initiated focusing on the bedrock topography and drift thickness. The primary objective this year for this large area in northwestern Alberta will be to evaluate the amount and quality of available data and develop a plan for the remainder of the study. Both investigations will also include a component focusing on the shallow bedrock and allow updating of the bedrock geology map of Alberta (Map 236).

Regarding the surficial drilling program, auger coring will be run northwest of Red Earth in the vicinity of the K4 kimberlite. The purpose will be to collect till samples for diamond indicator mineralogy and geochemical analyses, and to determine the local Quaternary stratigraphy. This information will help in defining the glacial dispersal fan that may have been formed as the ice flowed over the K4 kimberlite pipes.

Core showing variations in rhythmic bedding due to deposition in a glacial lake, Wabasca region.

The staff and all efforts of this project will complement and be integrated with the AGS surficial geology and geochemistry projects. Watch the next edition of Rock Chips for some of the results.❖

Collecting samples from core.

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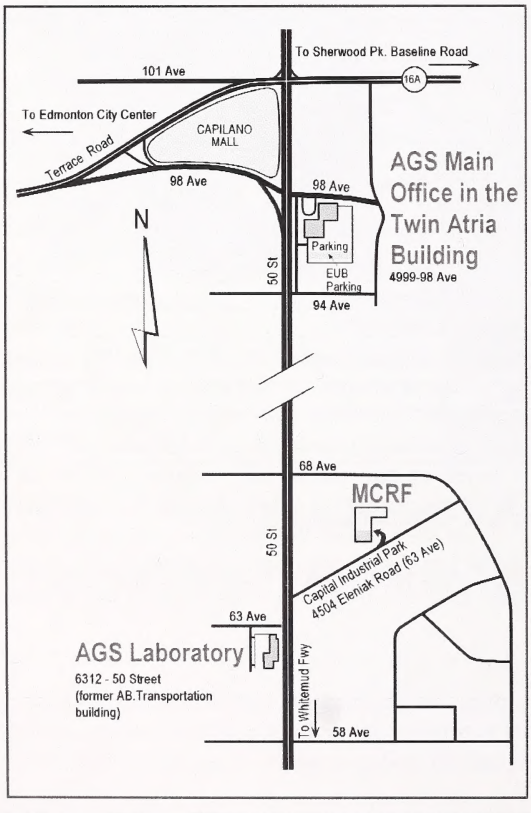
Recently Released AGS Publications

ESR 2001-01 GIS Compilation of Structural Elements in Northern Alberta, Release 1.0. 33.0 MB PDF. 2002. $20.00

ESR 2001-20 Alberta Kimberlite-Indicator Mineral Geochemical Compilation. 29.6 MB PDF. 2002. $20.00

GEO 2001-01 Bedrock and Stream Sediment Geochemical Analysis and Field Observations of the Sub-Cretaceous Unconformity, Northeast Alberta (NTS 74E and North Half 74D). 7.47 MB PDF. 2002. $20.00

GEO 2002-01 Observations of Naturally Occurring Hydrocarbons (Bitumen) in Quaternary Sediments, Athabasca Oil Sands Area and Areas West, Alberta. 3.37 MB PDF. 2002. $20.00



SPE 15 Petography of the Mountain Lake Pipe, Grande Prairie Area, Alberta, Canada. 14.3MB PDF. 2002. $20.00

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SPE 48 County of Barrhead No. 11, Regional Groundwater Assessment. 22.8 MB. 2001. $20.00

SPE 49 Sturgeon County, Regional Groundwater Assessment. 261 MB. 2001. $20.00

SPE 50 Cypress County, Regional Groundwater Assessment. 608 MB. 2002. $20.00

SPE 51 Regional Groundwater Assessment of Potable Groundwater in Woodlands County. 309 MB. 2002. $20.00

SPE 53 M.D. of Rocky View No. 44, Regional Groundwater Assessment. 580 MB. 2002. $20.00

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